Characterizing Broadband Acoustic Propagation Scintillation and Modelling Scattering and Reverberation for Sensing in a Random Ocean Waveguide

Purnima Ratilal
Northeastern University
360 Huntington Ave
409 Dana Research Center
Boston, MA 02115
phone: (617) 373-8458, fax: (617) 373-8627, email: purnima@ece.neu.edu

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http://www.ece.neu.edu/faculty/purnima/

LONG-TERM GOALS AND OBJECTIVES

The objective of this proposal is to (1) determine and quantify the effect of signal bandwidth and measurement time on ocean acoustic transmission scintillation statistics in both the saturated and partially saturated regimes for a shallow water waveguide, (2) develop and enhance unified physics-based models for broadband target scattering and reverberation in random range-dependent ocean waveguides by including the matched-filter, applicable to scattering from seabed and seafloor features, water-column scatterers such as bubble clouds, fish groups, plankton, and extended targets such as BBN hoses, submarines and marine mammals, including the potential effects of multiple scattering, dispersion, and shadowing or attenuation due to forward scattering. (3) Extract ambient noise characteristics from shipping, biological, geological, and physical processes and to apply these for environmental sensing.

APPROACH

The research effort involves developing and enhancing physics-based theoretical models for object scattering and environmental reverberation in *range-dependent* ocean waveguides. Acoustic data from the ONR-sponsored 2014 Nordic Seas experiment, the 2006 and 2013 experiments in the Gulf of Maine (GOME) will be analyzed to provide information on the temporal, spatial and statistical characteristics of the forward propagated acoustic field, biological clutter, scattered fields from man-made targets and environmental reverberation, as well as the oceanographic and environmental inputs necessary to validate our models.

WORK COMPLETED AND RESULTS

We have analyzed the ocean acoustic transmission data in the 300 to 1200 Hz frequency range from the Gulf of Maine 2006 experiment at very short source-receiver separations where the propagated acoustic field is expected to be only partially saturated in the shallow water environment. The complex spectral amplitude component of the received broadband signal is first obtained by Fourier transform and its distribution plotted in the complex plane. The amplitude and phase distributions are next derived for each spectral component of the received field. The complex spectral amplitude components have significant nonzero mean field, and therefore have a distribution that lie within an

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annulus offset from the origin in the complex plane. The phase distributions are found to be significantly non-uniform, especially at the low acoustic frequencies (see Fig. 1). The intensity distribution for the broadband and narrowband partially saturated field will be derived from the data to quantify the effect of bandwidth on potentially reducing the intensity standard deviation from spectral averaging. The amplitude and phase distributions for the data-derived narrowband (complex spectral amplitude) partially saturated field will be compared to the corresponding theoretical probability distribution models (Mikhalevsky, JASA1982). This will be then be used as a basis to derive a statistical model for the intensity distribution of broadband and time-averaged partially saturated acoustic fields. The methods will be applied to analyze the partially saturated broadband data measured using a towed FORA array from the 2014 Nordic Seas Experiment.

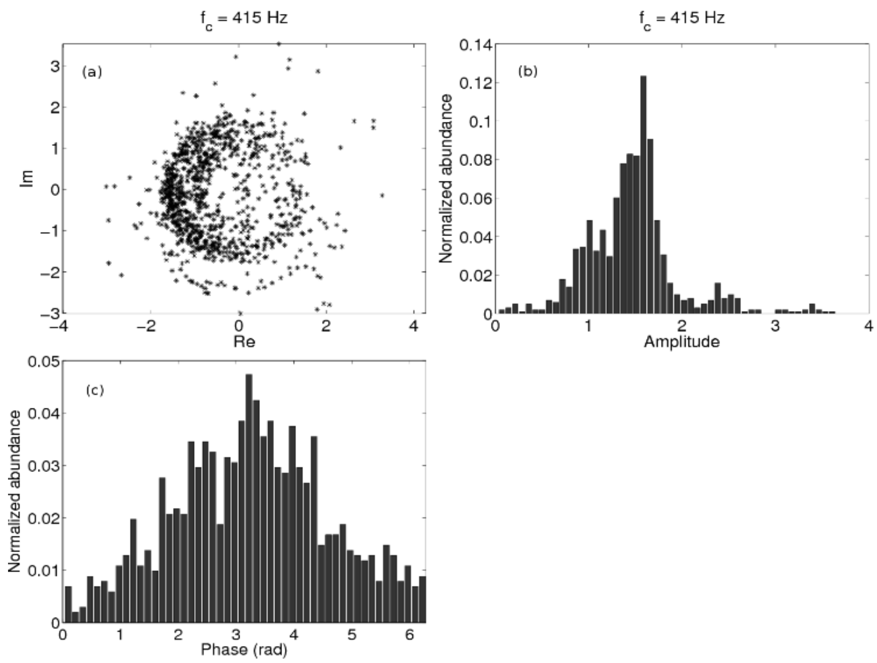

Figure 1: (a) Complex field, (b) amplitude and (c) phase distributions of ocean acoustic signal propagated over small source-receiver separations in the Gulf of Maine 2006 experiment. The complex field in (a) has non-zero mean and a phase distribution in (c) that is non-uniform so that the field is partially saturated.

2. Analytic formulation for broadband rough surface and volumetric reverberation including matched-filter range-resolution

An analytic formulation has been derived for the time-dependent broadband scattered field from a randomly rough surface based on Green's theorem employing perturbation theory. The matched filter is applied to resolve the scattered field within the range resolution footprint of a broadband imaging system. Statistical moments of the scattered field are expressed in terms of the second moment characterization of the scattering surface. The broadband diffuse reverberation depends on the rough surface spectrum evaluated over a range of wavenumbers, centered at the Bragg wavenumber corresponding to the center frequency of the broadband pulse and extending to wavenumbers proportional to the signal bandwidth from matched filter analysis. A similar approach will be applied to derive an analytic formulation for the time-dependent broadband reverberation due to rough surface

scattering in an ocean waveguide with multi-modal propagation. A corresponding analytic time-dependent broadband volume scattering model will derived from the Rayleigh-Born approximation to Green's theorem.

IMPACT/APPLICATIONS

We are comparing statistics of broadband and narrowband acoustic propagated signals in shallow waters at both short and long ranges so as to understand the measurements or sample sizes necessary to achieve desired accuracy in broadband active/passive sensing.

RECENT PUBLICATIONS

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